

Review of “Measurement report: Introduction to the HyICE-2018 campaign for measurements of ice nucleating particles in the Hyytiälä boreal forest” by Brasseur et al.

In this paper, the authors depicted the scope and detailed introduction of HyICE-2018 campaign, as well as inter-comparisons for both online and offline ice nucleating particle (INP) concentration measurement instruments based on 4-day data. The paper fits the scope of ACP, and is properly structured and well-written. The paper needs to be reviewed again after the authors address the reviewer’s concerns below appropriately.

Major comments

1. The paper uses too many vague and intuitive descriptions, such as “good” and “poorly”. Even though it is a measurement report, it’s still a scientific contribution to the community. Therefore, more scientific and quantitative descriptions are required.
2. There are too many figures than actually needed with repeated information. Some of them are barely mentioned in the text. Please carefully reconsider and prepare the figures.

Minor comments

Title: Please explicitly include “instrument inter-comparison” in the title and clarify the INP measurement condition, i.e., mixed-phase cloud formation condition, here and in abstract, and delete the full stop at the end.

P2L1: Even though not all INP instruments were run simultaneously, it would still be helpful to list the INP instrumentation engaged in this study here instead of using “additional instrumentation for measuring INPs” to give the readers more information on what type of INP instruments were used. Besides, please give the full name of SMEAR according to ACP requirement.

P2L14: It would be more logical to add a statement about ice formation pathways in the atmosphere (homogeneous and heterogeneous freezing) before introducing INP and heterogeneous ice nucleation.

P3L14-L15: Please specify the experiment condition (temperature and supersaturation with respect to water) of the organic IN references. Are they relevant to the experiment condition of this study?

P4L4: Please define a.s.l.

P4L8: Please rephrase the sentence “Multiple towers include...” to “There are several towers..., including ...”.

P5L11-L12: After heating the APS inlet, what did the authors do with the water vapor in the sampling flow? Will the water vapor condense inside the sampling line?

P5L14: Please change “operational” to “operating”. Also change it on P9L15.

P5L16: Please use consistent time format throughout the paper.

P5L17-L20: This sentence is irrelevant, please remove it.

P6L1: What makes the sampling “augmented”?

P6L12: Please rephrase to “offline IN activity/concentration measurements of particles collected on filters”. The original sentence reads as if the authors characterized INPs using the two DFA instruments, which is somehow beyond the instruments’ capability.

P6L15: Please define PINC, PINCii, and SPIN.

P7L5: Please add a comma before “some particles will...”.

P7L9: I suggest to replace “frozen and unfrozen particles” to “ice crystal and water droplets”.

P8L5-L6: Please rephrase “sampling intervals of 5 to minutes...”. Did the three CFDCs use different

background sampling time?

P8L11-L12: How were the concentrations during background and measurement sampling window determined? Were they converted from OPC counts and averaged over time? If so, please indicate the deduction and average before “concentrations”.

P8L24-L25: What’s the influence of such a large inlet flow rate compared to the small sampling flow rate? Is it possible that the vacuum pump driving inlet flow sucks from the instruments?

P8L26: What’s the RH_w range of the sampling stream at the dryer outlet?

P9L2: What is the second enrichment factor and how was it determined? Was it for the whole particle size distribution spectrum or for each size?

P9L16: Why is there a 1 °C lamina difference between PINC and PINCii to produce comparable results? How many thermocouples were used to determine PINC and PINCii wall temperature, respectively?

P9L17: What is the RH_w when the sampling air enters PINCii? Is it possible that the water vapor in the sampling stream condenses and affects the measurement and background results at PINC inlet?

P10L6: If the SPIN design in this study is the same as Garimella et al. 2016, then the statement on P7L4 “drawn through the center of the chamber” should be revised, since SPIN lamina does not lie along the chamber centerline.

P10L11: Did the authors characterize the VI concentrator? What’s the size-resolved enrichment factor? Please add references here. Please also add “(more details about the VI concentrator are provided below)” here.

P11L2: What is the exact concentration for particles larger than 1.3 μm based on APS data?

P11L3: Why are these large particles more pronounced? Please add references associated with the aerosol types presented in this study.

P11L3-L5: Did the authors measure particle size distribution before and after the VI concentrator with APS?

P11L10: $RH_w = 110\%$ seems to be above the water droplet survival line at -36 °C and -32 °C.

P11L11-L13: The particle concentration varies greatly from time to time in this study according to Fig. 7. It is common practice to fix CFDC lamina condition during field studies because it usually takes several minutes to change CFDC lamina S_i and temperature and re-establish equilibrium. Would the frequent alternation of both temperature and saturation in this study introduce more uncertainty? Are these results obtained with changing ambient condition and lamina condition at the same time comparable with each other? These descriptions might be irrelevant to the focus of this paper, i.e. inter-comparison of different instrumentation. So the author might just remove them.

P11L19: Please format the reference.

P11L23-L25: Will this air pumping process through OPC change aerosol population, and therefore INP concentration, in the chamber? Do the authors imply that the aerosols inside PINE chamber distribute homogeneously under changing pressure?

P12L5: Please clarify the particle transmission efficiency here and in the caption of Fig. 6 are for the sampling system upstream PINE rather than the PINE chamber itself to avoid misunderstanding.

P12L15-P13L9: Reads like introduction and adds little to the topic. Also between P13L9 and L10, do the authors mean one complete temperature spectrum in one test run?

P13L19-L20: Will the cleaning process change filter IN activity?

P13L30: How were the collected aerosols washed off and suspended? Mechanically or by supersonic? Please

elaborate.

P13L31: Please define “PCR”.

P13L35: Please add references for the camera and software if it were developed by KIT. Otherwise, please clarify the production company.

P14L6-L7: It would be better to use “100 °C water bath” here. Please also elaborate what container was used to hold the suspensions in the boiling water.

P14L22: Please elaborate.

P14L30: Please remove “and INPs”. These instruments can only provide vertical profile of ambient aerosols.

P15L13: What’s the relationship between soot and black carbon?

P15L21-L22: What’s the transition efficiency of the total aerosol inlet? Will the PM₁₀ inlet prevent large bio-aerosol from entering WIBS? Please elaborate more here.

P15L25-L27: What sampler did the authors use? Please add references.

P15L27-L30: Please add references for the cultivation process.

P16L12: The parenthesis should appear after “sensors”.

P16L10: Please specify the snow depth and temperature range during winter instead of the vague description “deep snow cover and cold temperature”.

P16L17: See the comments on these figures.

P21L14: Is there a reason why does PINE exhibit such frequent high variability? Is it valid to average INP concentration measured at different time (~30 min in this case)? Please elaborate.

P21L14: Could the authors change the 20% uncertainty to ± 1 standard deviation for PINE results to be consistent with the rest of the text?

P21L19: The trends of INP concentration for PINE and PINC during 18:00-20:00, Mar. 22, and around 11:30, Mar. 28 are opposite. Please explain why does this happen.

P21L10: By a factor of what is the SPIN measured INP concentration lower than that measured by PINE and PINC?

P22L8-L10: The trends between 12:00-13:00, Apr. 28 are not “very good” and “similar” even the authors attribute the deviations to different experiment temperature choice. Besides, is there a particular reason for the different T₁ and T choice?

P23L5: Why is the temperature information repeated again and again? Is there any finding in relevance to the daily and long-term temperature variation?

P23L25-L26: Does that mean ground-level measurements tend to over-present realistic INP concentration in tropopause?

P24L2-L3: Given the vast quantities measured in this field campaign, the readers would expect the authors to propose a novel parameterization applicable to boreal forest environment. This would add more to the paper and to the community.

P24L7: What measures did the authors take?

P25L8: What does “...detects INPs at temperatures up to 5 °C warmer...” mean? Does it mean that INSEKT has wider measurement temperature range?

P25L9-L10: What caused the INP concentration increase with the relatively stable aerosol population and meteorology condition?

P25L3-L8: It seems like the dilution process modified the IN active component in the suspension and exhibits a discontinuous drop in Fig. 14. The readers would expect more physicochemical analysis on the aerosol type and abundance in the suspension, rather than a vague and plain statement of “in the range of error bars”.

P25L13: Please remove “by”.

P25L13-L14: What factors caused the large deviation between different sampling time? The authors present diurnal meteorology and particle concentration profile with no analysis and investigation.

P28L5-L6: How was one standard deviation determined for each parameterization? The content in Fig. 16 caption should be elaborated more in the main text rather than not mentioned at all.

P28L8-L14: Please quantify “good agreement” and “poorly” since this is a scientific paper. The authors may also consider tune down the conclusion here since it is drawn based on one single data point for online instruments.

P28L9-L10: It seems like that the Tobo et al. (2013) parameterization overlaps more because it has larger uncertainty based on the description and figure.

P29L15-L16: Again, what does “...tends to detect INPs at temperatures up to 5 °C warmer...” mean?

P29L16-L18: Too many vague descriptions. Please quantify “good”.

P29L20-L23: Again, please tune down the conclusion here, since it is drawn based on very limited data.

P30L1-L11: Reads like introduction.

Fig. 1:

- The legend text size is too small.

Fig. 2:

- Would it be cleaner to add a column in Table 1 and include the sampling period? The daytime average temperature information appeared again in Fig. 7 and Fig. 10. Do the authors intend to show the correlation between temperature and what?

Fig. 3:

Panel a:

- Please specify “main chamber” and “evaporation section” in the plot.
- Supersaturation > 1 means $RH_i > 200\%$. I assume the authors use S_i to present saturation with respect to ice, rather than supersaturation here? If so, the definitions on P3L26 and P7L5 should also be modified.
- It would be better to draw background and measurement sampling periods (green and pink) to scale (e.g., 5 min background to 15 min measurement).

Panel c:

- Please align letter “T” with the arrow on the top right corner.

Panel d:

- The legend color of Expansion Chamber doesn't match (brighter red) with the plot.

Caption:

- L5-L6: Add a dash between “INP” and “temperature”.

Fig. 4:

- Please annotate the circled cross mark in the scheme. For example, it could be a virtual valve.

Fig. 5:

- Could the MFCs on the right part of this figure function normally in the setup? Where does the MFCs working pressure difference come from? Is there a needle valve to choke the external pump at the Excess out (free air)?

Fig. 6:

- It adds little to the paper. Could it be moved to appendix?

Fig. 8:

- The colors and legend position for Snow depth and WIBS total are confusing. It would be better to indicate panel (a) and (b) beside the legends.

Fig. 7-9:

- Recombination of the same experiment data set. Could it be reduced to two figures? For example, Fig. 9 could be a panel of Fig. 7.

Fig. 10:

- This figure is not self-explanatory. Missing legends and too much information placed in the caption.
- It adds little to the main text. There is just one statement about this figure between P17L18-P17L20. Therefore, it might better be moved to appendix.

Fig. 11:

- Caption L2: Please replace “with PINCii” with “for PINE and PINCii” to avoid misunderstanding.
- Would it be possible to incorporate inlet information listed in Table 2 in this figure? That way the readers can gain more knowledge regarding the difference between heating and inlet cut-off setups.

Fig. 12:

- Why don't the authors combine this figure with Fig. 11?
- If the authors select a temperature window of -29 °C to -32 °C here to cover the experiment temperature selected in this study, it would be more reasonable to draw two separate lines for -29 °C and -31°C for each parameterization, and draw a shading representing ± 1 standard deviation using different particle concentration or ambient temperature for the predicted INP concentration.

Fig. 11 and 12:

- Since this paper concentrate on instrument inter-comparison, the readers would expect a plot like Fig. 15.

Fig. 13:

- It might be more clear and straightforward to convert this figure to a table.

Fig. 14:

- The error bar color needs to be changed for either instrument.

- Why is there a drop of INP concentration around -18 °C for both instruments, even though only INSEKT used the diluted suspension?

Fig. 15:

- It might be better to use different symbols, rather than colors, to denote different measurement time.

Fig. 16:

- Add “on” before “March 28” in the caption.

Table 1:

- A list of abbreviations should be given somewhere.
- The sampling locations for INSEKT and μ L-NIPI are confusing. Are the filters used for both instruments from all three locations?